REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
04-28-2012	Masters of Military Studies Research Paper	November 2011 - April 2012

4. TITLE AND SUBTITLE

Fueling America's Transportation Requirements

5a. CONTRACT NUMBER
N/A

5b. GRANT NUMBER
N/A

5c. PROGRAM ELEMENT NUMBER
N/A

6. AUTHOR(S)

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5d. PROJECT NUMBER
N/A

5e. TASK NUMBER
N/A

5f. WORK UNIT NUMBER
N/A

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

USMC Command and Staff College
Marine Corps University
2076 South Street
Quantico, VA 22134-5068

8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

N/A

10. SPONSOR/MONITOR'S ACRONYM(S)
N/A

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
N/A

12. DISTRIBUTION / AVAILABILITY STATEMENT

Unlimited

13. SUPPLEMENTARY NOTES

N/A

14. ABSTRACT

American dependence on foreign oil is a strategic vulnerability. Advanced biofuels are able to provide some relief of foreign oil dependence. With recent advances in chemical and biological engineering, the potential of a new source of oil for America is emerging. This paper will assess the limitations and benefits that advanced biofuels may have on the Department of Defense (DoD) and American society. The DoD, with the support of the Department of Energy (DoE) and the Department of Agriculture(USDA), has provided an opportunity for American private sector companies to gain traction in making economically competitive biofuels. If this industry is able to produce advanced biofuels on a large scale, American dependence on foreign oil might diminish.

15. SUBJECT TERMS

Advanced Biofuels, Transportation Energy, Algae Biofuels, DOD biofuels

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Marine Corps University / CSC
Unclass	Unclass	Unclass	UU	40	19b. TELEPHONE NUMBER *(include area code)* (703)784-3330

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MASTERS OF MILITARY STUDIES

TITLE: Fueling America's Transportation Requirements

SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENT FOR THE DEGREE OF

MASTERS OF MILITARY STUDIES

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USMC Command and Staff College AY11-12

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Date: 5/1/12

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Date: 1 May 2012

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Executive Summary

Author: Major Ioanis S. Athanasiadis, USMC Reserve

Title: **Fueling America's Transportation Requirements**

Thesis: American dependence on foreign oil is a strategic vulnerability. Advanced biofuels are able to provide some relief of foreign oil dependence.

Discussion: With recent advances in chemical and biological engineering, the potential of a new source of oil for America is emerging. This paper will assess the limitations and benefits that advanced biofuels may have on the Department of Defense (DoD) and American society.

Conclusion: The DoD, with the support of the Department of Energy (DoE) and the Department of Agriculture(USDA), has provided an opportunity for American private sector companies to gain traction in making economically competitive biofuels. If this industry is able to produce advanced biofuels on a large scale, American dependence on foreign oil might diminish.

Preface: Fueling America's Transportation Requirements

This paper will examine how emerging technologies in biofuels can provide the United States with greater energy security. Although Americans use oil for many applications, the role oil plays in fueling our transportation requirements is the focus of this study.

The United States diversifies where it sources oil because its demand outweighs its supply. Diversification remains the key but that diversification must come from within. Recent advancements in biofuels have provided the United States new opportunities for diversification.

There have been many challenges in producing sufficient quantities of biofuels at prices competitive with the cost of oil. To overcome these challenges, the United States government has provided financial and research support. Without this support, companies would not be viable while developing their products. Although government support for advanced biofuel research is high, setbacks in this and other renewable technologies will affect future support. For each example of success, there is a mirror example of failure. The increasing international demand for oil has enabled biofuel research to continue, but proof of production at a level that can impact America's dependence for foreign oil remains evasive.

This paper will also address current and future applications of biofuels in the United States military. In the future, military units may deploy with a capability to produce biofuels in the field. The DoD is pursuing this and other methods of reducing logistics requirement of fueling its combat units in the field.

I would like to thank Dr. Adam Cobb, my mentor, for his patience, guidance, and stalwart dedication to ensuring I gained the maximum amount possible in writing this paper. Due to his efforts, I have a new appreciation for the complexities in the world of energy. He has wet my appetite to find new alternatives to energy challenges facing the Marine Corps.

Introduction

Over the past decade, the weapon of choice used against American forces has been improvised explosive devices. Vehicles with heavier armor are used to counter this threat. As vehicle weight increases, fuel efficiency decreases. The increased demand for fuel requires more fuel convoys. Understanding this correlation, the enemy has wisely targeted logistics convoys. In Afghanistan, an "estimated 6,000 fuel convoys are required on an annual basis. There is an average of one casualty for every 50 convoys".[1] To date, enemy attacks on fuel convoys have caused over 3000 causalities in Iraq or Afghanistan.[2] In one day, 54 tractor-trailers carrying fuel were destroyed. While the ensuing fire took 16 hours to bring under control, a NATO truck terminal was attacked, destroying an additional 22 fuel trucks.[3]

Colonel (Col) Robert "Brutus" Charette, the Director of the Marine Corps Expeditionary Energy Office (E^2O), stated that 70 percent of logistics in Afghanistan is used to transport water and fuel. At a current rate of one attack per every 17 convoys, any actions that can reduce the amount of convoys will equate to fewer causalities. A snapshot picture of Helmand Province provides a troubling picture of how dependent American forces have become on external support. On a daily basis 80 trucks are needed for bottled water and 54 trucks are required to transport 260,000 gallons of fuel. At the current rate of $8.37 per gallon, that equates to $794 million each year in fuel costs for Helmand Province.[4]

In regard to self-sustainment and efficiency, the Marine Corps has moved in the wrong direction over the past decade. The Corps has increased its footprint by 250% for radios, 300% for computers, and twice the amount of vehicles. The vehicles we have added are heavier and less fuel efficient. The primary three vehicles used in Helmand Province, the HMMWV, MTVR, and MRAP average mile-per-gallon rates of 8.0, 4.3, and 4.0 respectively. Although there are

projects in the works to increase their fuel efficiencies up to 25% above their current levels, the amount of fuel required to keep these vehicles moving is a vulnerability to the mission.

Beyond the increase in energy requirements for tactical vehicles, the Marine Corps struggles to balance increased energy demands that improved quality of life cause. Air conditioning, improvements in food, and better entertainment aboard the forward operating bases (FOB) all come at the price of an increase in required fuel. The amount of generators used in Afghanistan today is equal to the total amount of generators the Marine Corps had in its entire inventory ten years ago.

To counter this downward trend in efficiency, the Commandant of the Marine Corps, General Amos, charged Col Charette's E^2O team to develop methods to ensure by 2025, Marine expeditionary Forces can maneuver from the sea and sustain C4I and life support sustainment in place. The only liquid fuel needed will be for mobility systems. These systems will be more energy efficient than systems are today. To achieve this goal, the Marine Corps must change its mindset, embrace the ethos of austerity and self-sufficiency over the comforts in which we have become accustomed, and understand the correlation energy efficiency has to saving time, money, and lives.

In 2006, Major General Richard Zilmer, the Commander of the 1st Marine Expeditionary Force in Iraq, requested renewable-energy gear for his Marines. His urgency of needs request started the process of getting solar panels to Marine units. Following a second appeal in 2008, "scientists at the Office of Naval Research cobbled together a solar-and-battery combination small enough to be transported on HMMWV's, big enough to power the gear at a combat outpost, and rugged enough to withstand tough field conditions."[5]

India Company, 3d Battalion, 5th Marines was chosen by E^2O to conduct a pilot program using solar panels to supply sufficient energy for their radios and combat operations center during their seven month deployment to Afghanistan.[6] By eliminating the requirement to power a generator with diesel, the Marines were able to reduce the need for resupply convoys to their locations. India Company also used small solar blankets to charge their batteries. Although they were initially opposed to the idea of trading diesel power for solar energy, India Company embraced the idea once they received training on the solar system during their pre-deployment training. Following their success, General Amos decided to accelerate the introduction of the solar panel kits to all Marine units in Helmand Province.

Solar kits are helping reduce or eliminate the demand for fuel at small combat outposts, but the large FOB's continue to require substantial fuel. Aside from the quality of life improvements, FOB's house the combat vehicles needed for mobility within a large area of operations (AO). In Helmand Province, the constant threat of improvised explosive devices and its substantial geographic size makes the use MRAP vehicles for mounted patrols necessary. The Marine Corps understands dependence on fuel puts Marines in danger and is investing in ways to mitigate this risk.[7] With the exception of changes in Marine behavior and marginal increases in fuel efficiency, no viable solutions have emerged that can have a significant effect on reducing the amount of fuel convoys needed to supply the Marine Corps combat vehicles in Helmand Province.

The ability to supply our FOB's with fuel is not a capability that is always certain. Fortunately, albeit at a high price, America is still in a position of power great enough to replace each destroyed fuel truck with a new shipment. If, however, the enemy can disrupt convoy support to any of our FOB's for an extended period of time, combat effectiveness will decrease

due to reduced communications, mobility, hygiene, and morale. In addition to enemy influence, other factors, such as a dramatic shift in world oil supply or a change in American support by the nations surrounding Afghanistan can affect our ability to supply our forces.

History is full of examples of how a superior military force was defeated through its inability to sustain its forces. Lee, Napoleon, Rommel, and countless other exceptional generals have suffered defeat because their forces could not gain the necessary reinforcements and supplies to win. In the protracted war between the U.S. and its' adversaries in Afghanistan, the possibility of U.S. forces finding themselves suffering the same fate as the great military forces before them – not through might, but through supply – is a real possibility. It may seem unfeasible, but when Pakistan closed its supply routes following U.S. raids and a friendly fire incident, the monthly cost of supplying troops in Afghanistan increased by over 500 percent.[8]

Although the true cost of fueling forces in remote outposts is difficult to ascertain, conflicting reports show top prices anywhere between $8 and $600 per gallon.[9] When analyzing such a dramatic variance in price, it is difficult to determine what variables the sources took into account. One source might reflect the price of the fuel coming out of the pump while another price might reflect the cost of causalities, infrastructure improvements, or the aircraft fuel needed to transport it to an outpost. The cost data is easily manipulated to support the objectives the source is trying to convey. Nonetheless, the cost and difficulty of providing fuel to combat outposts are high. Even if an outpost provides a tactical advantage, U.S. forces may be forced to withdraw if it is too costly to support. For this reason, the dependence that combat troops have on fuel plays a key role on how they can engage the enemy.

Fueling the Marine Corps in combat is only part of the challenge. To power its vast fleet of civilian and tactical equipment, the Marine Corps Energy Strategy is focused on fuel

efficiency and renewable energy innovations.[10] Diesel is what the Marine Corps uses to power nearly all of its vehicles and combat equipment. The Marine Corps is experimenting with diesel made from different forms of organic matter – known as advanced biofuels. The intent is by introducing biofuels as an additional diesel source, the Marine Corps is reducing its vehicle fleet and tactical equipment fuel vulnerabilities in the same manner solar and wind power diversification is reducing facility energy vulnerabilities.

In 2009, President Obama issued an executive order directing the DoE and General Services Administration (GSA) to use biodiesel blends in diesel vehicles for the entire federal fleet.[11] In theory, this directive from the President is a great step in moving America away from foreign oil dependence. Unfortunately, this is an example of good initiative outpacing the realities of current capability. At this time, or in the foreseeable future, there is not a supply capability able to meet the requirements set forth by the President.

When President Obama issued his executive order, combat vehicles and equipment were exempt because of the rigors of combat environments and the fact that equipment readiness in combat has life or death consequences. The Marine Corps, following the President's intent, received waivers to test biofuels in tactical equipment. The tests, conducted both in garrison and in combat, have been highly successful.

When seeking alternatives to diesel, the Marine Corps has stipulated that only fuels that do not require a modification to its equipment can be used. This requirement, known as a "drop-in" capability negates certain sources of fuel, such as hydrogen, from consideration. Over a two year period, Marine Corps Systems Command tested a drop-in biofuel blend on two Light Armored Vehicles. The tests focused on the effect extreme temperatures had on the biodiesels

sitting dormant for extended periods. The results of the tests indicated the biodiesels did not appear to degrade the performance.[12]

On a small-scale, proof-of-concept, mission in Afghanistan last year, Sergeant (Sgt) Brian Nelson, a Marine with a chemical engineering degree, was successful in using cottonseed oil acquired from the local Afghan economy to operate a 10kW generator and an Environmental Control Unit (ECU) aboard his forward operating base.[13] During the experiment, Sgt Nelson used a blend of 20 percent cottonseed oil that he acquired from the local Afghan economy with 80 percent Jet Propellant 8 (JP-8).[14] According to the after action report by the Marine Corps E^2O, the testing was successful. If this concept were matured and used each time Marines deploy, it might change how Americans fight in future conflicts and wars.

In addition to the efforts the Marine Corps E^2O is working on to reduce battlefield energy requirements, they are also working towards the goal of enabling all Marine Corps Bases to reach net-zero energy by 2020. To attain this goal, the implementation of solar and wind energy systems is underway. Like any new venture, it is taking time to work through the nuances of converting our bases to the new systems. Dealing with different state and local regulations, pushback from regional power supplier, developing and maintaining a resident knowledge of the best systems to invest in for each installation, and support from the manufacturers are a few of the challenges that each base will encounter. Once complete, by diversifying the sources of energy used on its bases, the Marine Corps will reduce its vulnerabilities of depending on the public energy grid.

As the Marine Corps has become more dependent on electric power to manage its C4I platforms, its vulnerability has also increased. With a public power grid that is susceptible to cyber-attack and, in many cases, is in need of substantial refurbishment, making Marine Corps

bases self-sufficient will improve national security, reduce the demand on the local power grid, and save tax-payers money in the long term. Like the combat outposts that are using solar panels for their energy needs, wind and solar energy aboard our Marine Corps bases only addresses the energy needs of its facilities – its vehicles will still require fuel.

A Possible Long-Term Solution – Advanced Biofuels

General Amos is not the first Marine Commandant to address his concerns about the vulnerabilities of providing reliable fuel to his forces in austere, hard to access locations. General Hagee, the 33d Commandant, questioned the viability of producing biofuels aboard FOB's, thus reducing or eliminating the need for fuel convoys.[15] His concept was sound, but well ahead of its time. As General Hagee was aware, biofuels were nothing new. When Henry Ford was developing the Model T, he intended to power it with biofuel produced from either ethanol or peanut oil.[16] The challenge was not the production of biofuels; it was the challenge of producing biofuels fast enough and in sufficient quantities.

The reason Henry Ford used oil instead of biofuels was because oil was plentiful, easy to access, and cost less than biofuels. This has remained the case for the past 100 years. Oil has served as an exceptional source of fuel, but as its cost has increased, so has the renewed interest in biofuels. At the highest levels of the U.S. government, biofuel support is gaining traction. Congress set aside $800 million of the Recovery and Reinvestment Act of 2009 for biofuel research and development. Several companies that demonstrated the ability to produce transportation grade biofuels were authorized funding.[17]

Governmental support enables promising companies the means to begin production. With any new venture, however, good ideas are only part of the equation. Proper management, infrastructure, stable supply and demand, a capable workforce, tax incentives, competitive

pricing, marketing, and countless other aspects of business determine the difference between success and failure. Government support can help with some of these challenges, but success ultimately depends on the ability of each individual company's resilience and ingenuity. Even with a substantial governmental investment, the probability of success for most companies is historically low. With the financial woes that America is currently experiencing, there is little tolerance for failure.

In 2010, "the Navy paid $425 per gallon for a batch of test biodiesel, as compared with about $3 per gallon for the old-fashioned stuff."[18] Following the test, an additional 450,000 gallons of advanced biofuel was purchased, the single largest purchase of biofuel in government history, for jet fuel training at a cost of four times more than conventional jet fuel. Secretary of the Navy Ray Mabus authorized the purchase to encourage the development of advanced biofuels and other renewable energy systems.[19] Since then, the Navy announced an additional investment of $510 million over the next three years to produce advanced drop-in aviation and marine biofuels to power military and commercial transportation.

This investment, along with other government initiatives, indicates that the Obama Administration is dedicated to providing the private sector with the financial backing and the stability of a reliable, large-scale consumer. These guarantees by the government will likely come with stipulations and substantial oversight. In a down economy, even when America imports nearly $1 billon each day in foreign oil, a $510 million purchase from the Navy on biofuel that costs significantly more than regular oil raises concerns. The cost of getting the production of advanced biofuels up to a commercial level is substantial. With a military commitment to purchase advanced biofuels for an extended duration, the interest of private enterprise has increased.

"The US Air Force wants its entire fleet of jet fighters and transport aircraft to test-fly a 50-50 blend of petroleum-based fuel and other sources – including algae – by next year."[20] The Department of the Air Force is awaiting the cost of advanced biofuels to become competitive with fossil fuel prices before making large-scale purchases. With a fleet of over 6,000 aircraft, the Air Force uses more energy than any other agency in the government. Over 80 percent of its fuel goes into the fuel tanks of its aircraft -- about 2.5 billion gallons a year.[21] Once the cost comes down, the Air Force's commitment to purchasing advanced biofuels might play a big role in encouraging additional advanced biofuel production within the private sector.

The DoD is the single largest consumer of oil in America. The assurance by the DoD that the biofuels produced will be purchased for several years allows companies to gain efficiencies in their projects. The DoD fuel requirements can assist in the establishment of the biofuel industry and help America reduce its dependence on foreign oil. "Direct consumption of petroleum accounted for more than three-quarters of DoD's energy use in fiscal year 2010 -- costing $13.4 billion".[22] With the 2012 National Defense Authorization Act, long term funding is assured, enabling the DoD to serve as a leader in the efforts to develop large-scale biofuel production capabilities.

In accordance with the 2012 National Defense Authorization Act, the Secretary of Defense will provide Congress a list of potential biofuels suppliers. These suppliers will receive multiyear contracts to provide biofuels to the DoD. Support from the private sector through these initiatives will help shelter the DoD from future price instability and any interruptions in supply. In theory, economics of scale will kick in and enable the price of advanced biofuels to continue to drop -- benefitting taxpayers. If this becomes the case and production can increase significantly, biofuels might have an impact on America's dependence on foreign oil.[23]

The 2012 National Defense Authorization Act expounded on a mandate from the previous year that addressed the expectations Congress placed on the DoD to revamp energy performance goals and programs. In 2011, the focus was squarely on the conservation of the energy used on military facilities with little mention of the energy demands of the transportation fleet.[24]

One challenge the Obama Administration has is that the private sector must match at least dollar-for-dollar when purchasing advanced biofuels. This governmental stipulation is intended to reduce corruption, protect tax payers, and increase efficiencies. If a product has a viable use beyond the military, the one-for-one dollar rule applies. "Under Title III of the Defense Production Act, any new production capacity created by the kind of public-private partnership the Navy envisions must not outstrip the demand in the marketplace. Said another way, the new biofuels industry can't be allowed to produce more of its own government-subsidized product than the nation's economy can buy, lest it become dependent on ongoing subsidies for its survival."[25] At first look, this may appear as a bureaucratic hurdle, but there are many private sector companies, mainly airlines, that are willing to pay above the current rate of jet fuel for biofuel. It may not appear to make business sense, but there are many ways the government can incentivize private companies to support their projects. In addition, using biofuels can provide good publicity to the growing populace of consumers that are looking to patronize the most eco-friendly options available.

After the U.S. government, the airline industry is the second greatest consumer of fuel. United Airlines has also purchased large quantities of advanced biofuels from Solazyme and has flown the world's first commercial aviation flight on algae-derived biofuel. Starting in 2014,

United Airlines will purchase 20 million gallons of algae biodiesel a year from Solazyme.[26] Alaska Airlines has also had flights powered by biofuels.[27]

Ultimately, supporting the growth of the biofuel industry is considered a matter of national security. By exercising government authority to encourage biofuel alternatives, Americans will become less vulnerable to global turmoil. In addition, the emergence of biofuel jobs will keep American money in America and promote industrial ingenuity that enabled the American economy to thrive over the past century. During a State of the Union address in 2011, President Obama made his commitment clear when he stated "with more research and incentives, we can break our dependence on oil with biofuels." [28]

"To help advance the commercialization process, the Obama Administration has set a goal of breaking ground on at least four commercial-scale cellulosic or advanced bio-refineries over the next two years. In addition, President Obama has directed the USDA and DoE to speed the development of drop-in biofuels substitutes for diesel and jet fuel. Competitively-priced drop-in biofuels could help meet the many of the largest consumers of fuel, from the DoD to commercial aviation and shipping."[29]

One beneficiary of 2009 Recovery and Reinvestment Act is the San Francisco based company Solazyme. The award helped Solazyme increase annual production from tens of thousands of gallons of its algae "drop-in" oil to an annual production capacity of over half a million gallons. Additional expansion could yield capacity in excess of 100 million gallons per year at each of its facilities.

Solazyme delivered 1,500 gallons of algae-based jet fuel for the Navy's testing and certification program.[30] Solazyme is currently working to provide the Navy with 100,000 gallons of jet fuel and 350,000 gallons of marine distillate fuel. The fuel will be used as part of the

Navy's efforts to develop a "Green Strike Group" composed of vessels and ships powered by biofuel. The Navy's goal is to source 50 percent of its energy from renewable sources by 2020.[31] "The Navy, which uses 3.36 million gallons of fuel daily, has made the pledge of getting 50 percent if its fuel from fossil fuel alternatives by 2020. At current demand levels, that would work out to around 613 million gallons of biofuel a year."[32]

Solazyme claims that it can produce 100 million gallons of biofuel each year at its Riverside, PA facility. To put that into perspective, Americans use 380 million gallons of fuel from foreign countries daily. If Solazyme's productions rates are accurate, sustainable, and can be replicated at new facilities, it would require 680 similar plants to completely eliminate the U.S. requirement for foreign oil.

Solazyme grows the algae for their biofuels in closed containers, similar to a brewery. They have found that the speed of growth is greatly increased when sugars are introduced to the algae. Sugars can come from indigestible sources, like wood chips, and do not have to compete with food production. The advantage of this process is not only the increased rate of production, but it also opens the possibilities of growing algae in regions of the country that have environments that would otherwise not support year round production. By establishing plants near consumers, the cost of distribution would decrease.

Solazyme is not without its challenges. Even with $22 million in stimulus cash used to build a biofuel factory in Louisiana, the firm was unable to turn a profit when competing against gas prices of $3 per gallon. During the last quarter of 2011, Solazyme posted a $15.6 million loss. When contact directly, it was not possible to ascertain from Solazyme if these losses were due to initial challenges of starting up the new facility or if the process of growing, refining, and distributing their biofuels had not reached the efficiency necessary to compete with regular fossil

fuel based fuels. Due to proprietary concerns, Solazyme was not able to share the breakdown of the byproducts they extract from their algae. In addition to biofuel, it is clear that chemicals, foods, and cosmetics are also made during the refinement of their algae oil.

If the losses Solazyme posted in Louisiana are not a short term challenge but an indication that producing high-yield algae based biofuel is not yet cost competitive, the U.S. government must keep faith and continue supporting new ventures. Solazyme might be the answer to America's desire to break its dependence on foreign oil or it might be another example of a good idea company that is unable to find long-term success.

A company with many similarities to Solazyme, Range Fuels, received $162 million in federal and state loans to produce cellulosic ethanol. The company built a new factory in Georgia, claiming it could produce up to 100 million gallons of ethanol from wood chips. The firm didn't produce a drop of marketable fuel before going bankrupt in January 2011.[33]

Any embarrassment the Obama Administration has experienced from the biofuel industry pales in comparison to that of another renewable energy industry, solar panels. Solyndra, a California based solar panel manufacturer, received $535 million in taxpayer funds before it went bankrupt. Preceding its demise, President Obama touted it as a prime example of how green technology could provide jobs and make enough panels to replace eight coal-fired power plants. Unfortunately for Solyndra, it was unable to compete against China's cheap labor and subsidies. Ultimately, the most cost efficient product prevailed -- Solyndra lost.[34]

When competing against socialist countries like China, America's capitalist system of economics has many advantages but can struggle on startup projects of strategic significance. China is able to leverage its cheap work force and focus it national resources on long-term projects without the same scrutiny the American government receives. In China, if a company

like Solyndra fails, the political elite are not affected. In America, risky ventures that fail are used as political fodder during elections. This can influence Capitol Hill to shy away from investment in new technologies in favor of safer, albeit shortsighted, solutions.

Biofuels and the Department of Defense

The private sector is not the only player in advanced biofuel research. The DoD, through the Defense Advanced Research Projects Agency (DARPA), is conducting research on algae based biofuels. DARPA is an organization within the DoD that focuses on breakthrough technologies for the U.S. military. Many technologies developed by DARPA have practical uses that benefit the U.S. National Strategy well beyond the confines of the DoD. Biofuel research falls within this category.

DARPA chose Hawaii for its algae biofuel research because of its favorable climate for year round algae production. Equally important, over 90 percent of Hawaii's energy needs are met by importing oil.[35] The intent is that research and development of advanced biofuels in Hawaii will will help lessen Hawaii's need to import oil. Since the cost of fuel is higher in Hawaii, it is easier for biofuel production to attain a competitive price point.

Algae biofuel faces two challenges before its available to mainstream America. The first challenge is cost. DARPA has extracted oil for as low as $3 per gallon. The expectation is that costs will continue to drop, perhaps to as low as $1 per gallon within the next few years. According to the DARPA Program Manager of the biofuel program, Dr. Robert Mantz, the $1 per gallon goal will make algae based biofuels price competitive with imported fuels. "The support for [advanced biofuels] is part of a broader mission for the US military to obtain half of its fuel from renewable energy sources by 2016."[36] In addition to the cost of production, the cost of refinement, taxes, distribution, and retail fees also drive the total price of fuel.

Increasing the scale of production of algae biofuels is the second challenge. According to Dr. Mantz, each acre at the Hawaii facility can produce enough algae to make 1,000 gallons of biofuel annually.[37] Because algae can grow at a fast rate, it can can produce "more than 80 times more oil per acre than corn"[38] Although this sounds impressive, growing algae in an open pond, as is the case in the current DARPA research in Hawaii, does not produce sufficient quantities quickly enough to have a profound effect on America's dependency on foreign oil.

DARPA's Hawaii project and Solazyme represent two different methods of growing oil rich algae that is capable of producing advanced biofuels. Although both entities claim their products are on the cusp of becoming cost competitive when compared to fossil fuels, neither DARPA nor Solazyme has provide an firm timeline when this will become a reality.

An enduring challenge in the production of oil from algae is the amount of fresh water required. In an open pond system, over 3,000 gallons of water are needed to produce a gallon of biodiesel. Even with 84 percent of the water returning to the environment, the rest is lost by either pond evaporation or drying. If the water is recycled, the ratio can decrease to a rate of 480 gallons water to one gallon of biodiesel – still too high to serve as a long term solution. No matter how much water is recycled, the water lost from drying and extraction is unavoidable.

To counter the drawback of using precious freshwater, many strains of algae are grown in seawater and wastewater. Using seawater or wastewater can reduce the freshwater requirement by as much as 90%."[39] Closed systems, like the one used by Solazyme, do not lose the same amount of water through evaporation then open ponds, but water is still lost in the extraction process. For algae biofuels to grow as a viable source of fuel, the amount of fresh water needed for production must continue to decrease.

Extraction of oils from algae is becoming increasingly efficient. Current methods use either a mechanical or chemical processes. The DoE at Los Alamos is researching the use of ultrasonic technology to break open the algae cells and "separate the oil, proteins, and water from one another".[40] The use of use of ultrasound technology has provided an increase in efficiency, quantity, and cost of extracting oils from algae.[41] At a large scale, with production facilities harvesting millions of gallons of algae, a low cost method of extracting oil from water is critical. This new method of separation may lower the cost of production by "multiple orders of magnitude".[42] Los Alamos believes that a portable, ultrasonic, algae harvesting device that can concentrate 25 gallons of algae per hour for less than a penny per gallon. If this becomes commercially available and water used to grow the algae is efficiently recycled, algae derived biofuels that are cost competitive will move closer to the realm of reality.

Biofuel Drawbacks

Pure biodiesel (B100) can have the following adverse effect:

- It is not compatible with some metals and plastics
- High sediment levels are found when in contact for long periods with copper, lead, tin, or zinc
    - Certain metal containers cannot be used for storage
    - Filters may clog more frequently
- It can permeate some common plastics over time
    - Certain plastic containers cannot be used for storage
- It starts to solidify at higher temperatures then standard diesel
    - It starts to cloud at 35º to 60ºF
    - As the viscosity begins to rise, stress on pumps will increase

- Heated fuel lines and tanks may be needed
- It may soften and degrade certain types of rubber compounds used for hoses and gaskets and may cause them to leak.[43]
- Chemical are needed to separate the fats from the oils
- Glycerin, a highly explosive material, is a byproduct of biofuel refinement[44]
- Substantial requirement for water

It is important to note that B100 is not what is used in equipment, but a mixture of 10 to 20 percent of biodiesel with conventional diesel (JP-5 or JP-8). Biodiesel blended with conventional diesel has not demonstrated any of the listed drawbacks. There are methods to chemically alter B100 to reduce or eliminate its adverse effects on hoses and gaskets, but for now it appears that blending biodiesel with JP-5 or JP-8 is the most cost effective alternative. Like with ethanol used in our automobiles, biodiesel has lower energy density than diesel. When mixed in a 20 percent biodiesel to 80 percent diesel blend (B20), the reduction in fuel economy is below 2 percent. In a tactical environment, tests have shown that B20 works well, when mixed with cold weather diesel, at temperatures down to -4F.[45]

Before Gen Hagee's vision of a FOB producing its own biofuel can become a reality, a few challenges must be overcome. First, a resilient, fast growing, high oil content algae must be readily available. Second, growing the algae cannot be water intensive. Third, if glycerin is produced during the refinement of the algae, measures must be taken to ensure it never falls into enemy hands and used against coalition forces. Ideally, another use for it, such as mixing it with foodstuff for swine needs to be determined. Lastly, current refinement technology requires substantial chemicals to refine biofuel from algae. The logistics burden of transporting the

necessary chemicals must be substantially less than the burden of transporting fuel. Additionally, the chemicals cannot be cost prohibitive, too volatile to transport or store, or difficult to acquire.

If these challenges are overcome, one day an algae pond or algae brewery may become one of the first priorities when establishing a FOB. Marine Corps engineer units might deploy with mobile refineries capable of transforming algae to biodiesel. In addition to growing algae for biofuel, contact teams comprised of Marines with agriculture and engineer training could seek other local sources of biofuels; paying close attention to any second or third order effects of the source of fuel procured. If successful in finding suitable sources, business relationships could be established, thus helping pump money into the local economies. If local sources of biofuels are not available, the contact team can work with locals on long term projects to establish farms that produce biofuel but do not reduce the local food or water supply.

During site assessments in Afghanistan, members of the USMC E^2O, following up on the success of Sgt Nelson's cottonseed test, looked into local crops that could produce biodiesel. Even poppy seed crops, used by the Taliban to produce and sell opium, were considered as a possible source, but scrapped for obvious reasons.[46] If approved, the locals could choose between growing poppy seeds for the Taliban's drug trade of for Afghan and coalition forces biofuels. For the United States, the benefit of the biodiesel produced form poppy seeds is not worth the stigma associated with encouraging another nation to grow a crop known to make heroin.

Each FOB could compare the costs of importing fuel, growing it on the FOB, acquiring it from local merchants, or a combination of the three to determine the best method. Long term benefits would include fewer casualties from convoy attacks, leaving behind a self-sustaining

economy for the local populace, and improved relations with the community. In such a scenario, even a marginal success would save lives and provide a substantially better climate for U.S. troops.

As the greatest customer of transportation fuels, the DoD can serve as a stabilizing factor for emerging biofuel producing companies. Advanced biofuels will not replace oil, but they can serve an additional source of fuel, thus reducing America's dependence on foreign oil. The U.S. Government should use every opportunity to spur the private sector into developing and using biofuels.

At the strategic level, 20 percent of oil imported into the U.S. comes from nations that are considered dangerous or unstable. That equates to over $100 billion a year going out to nations that may, at best, have cold relations with the United States.[47] In many cases, it strengthens the capabilities of foreign governments hostile to U.S. interests.[48] Even in Afghanistan, much of the money we spend to fuel our forces ends up in the pockets of our enemies.[49]

Why it is Important Now

Future energy estimates by the International Energy Agency are concerning. By 2035, China is expected to consume nearly 70 percent more energy than the United States. The predicted energy consumption growth rates in India, Indonesia, Brazil and the Middle East are even faster than in China. As economic growth increases demand for personal automobiles, the increase in oil demand will come from the transport sector in emerging economies. By 2035, the total number of passenger cars in the world will double. Although efficiency gains and the development of new technologies has enabled U.S. decrease the amount of foreign oil its importing, American dependence on foreign oil remains a strategic vulnerability.50

"The United States of America cannot afford to bet our long-term prosperity and security on a resource that will eventually run out."[51] The DoD should continue to support the advancement of alternative transportation fuels. This must occur while balancing mission effectiveness. The ability of the DoD to provide the necessary resources for alternative fuel innovation and experimentation at a large-scale can help the U.S. national security.[52]

Biofuels can help America's economic security. Money that America is currently paying for foreign oil would remain in America. By reducing American dependence on foreign oil, antagonistic governments will lose some of their political influence. The exponential increase of the world's population is causing a substantial strain on resources; primarily food, water, and oil -- biofuels can fuel industry to help provide all three of these resource shortfalls.

CONCLUSION

In conclusion, fossil fuels were a driving force in the ability of the United States to rise to, and remain, a global power. As the global oil market has become more volatile, the necessity for America to find new, innovate ways to fuel its transportation needs are clear. Petroleum is a gateway energy source that has served as the fuel of choice between the age of coal and the age of advanced biofuels. The time has come for American society to begin waning itself off of oil. America's transformation to biofuels can spur the American economy by providing jobs to farmers, refinery workers, and suppliers. It will also keep American investment in America while eliminating the exodus of American dollars to governments that are hostile to the United States. With the support of the U.S. Government via the DoE, United States Department of Agriculture (USDA), and DoD, private industry has an opportunity to transform advanced biofuels into the fuel that will support America's transportation needs.

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Figure 1
2010 Energy Consumption by Source and Sector
EIA.Gov

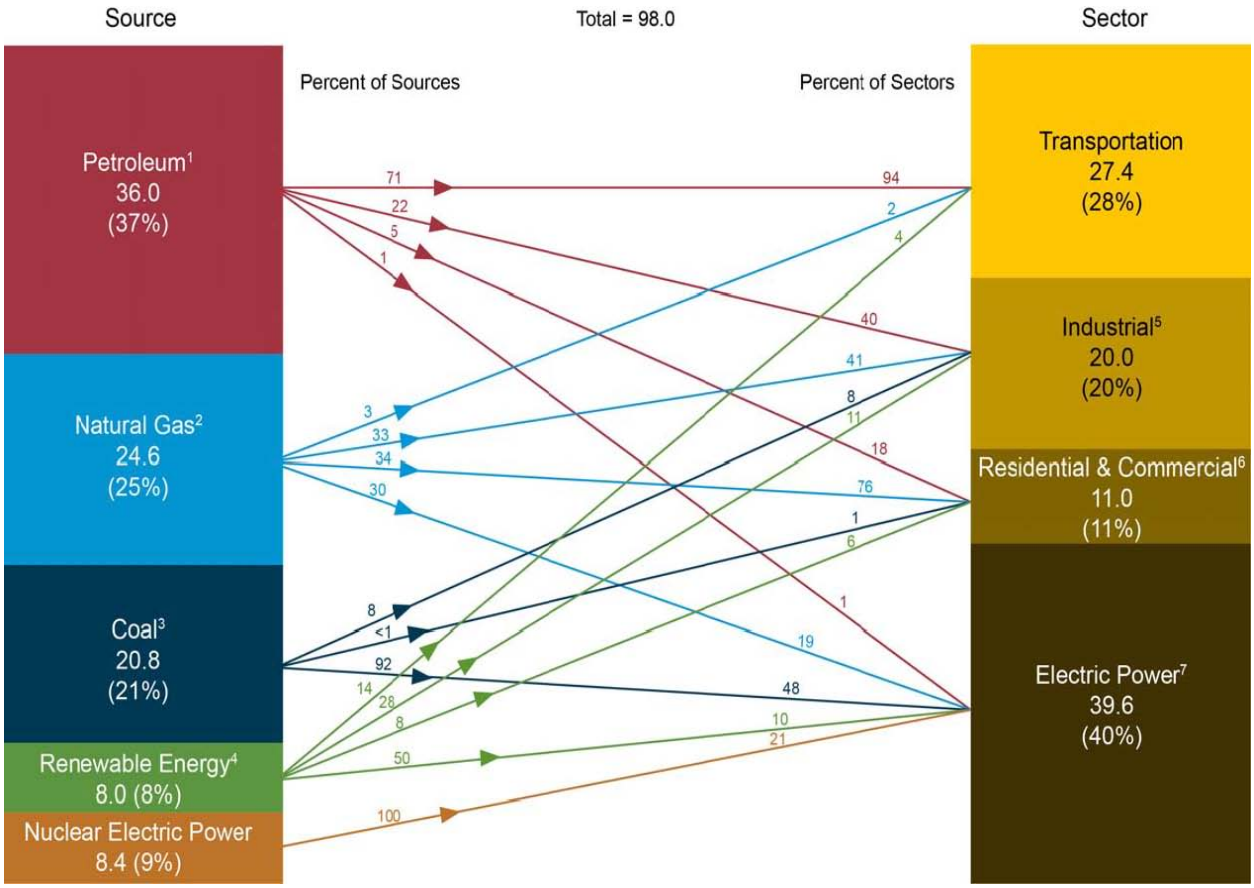
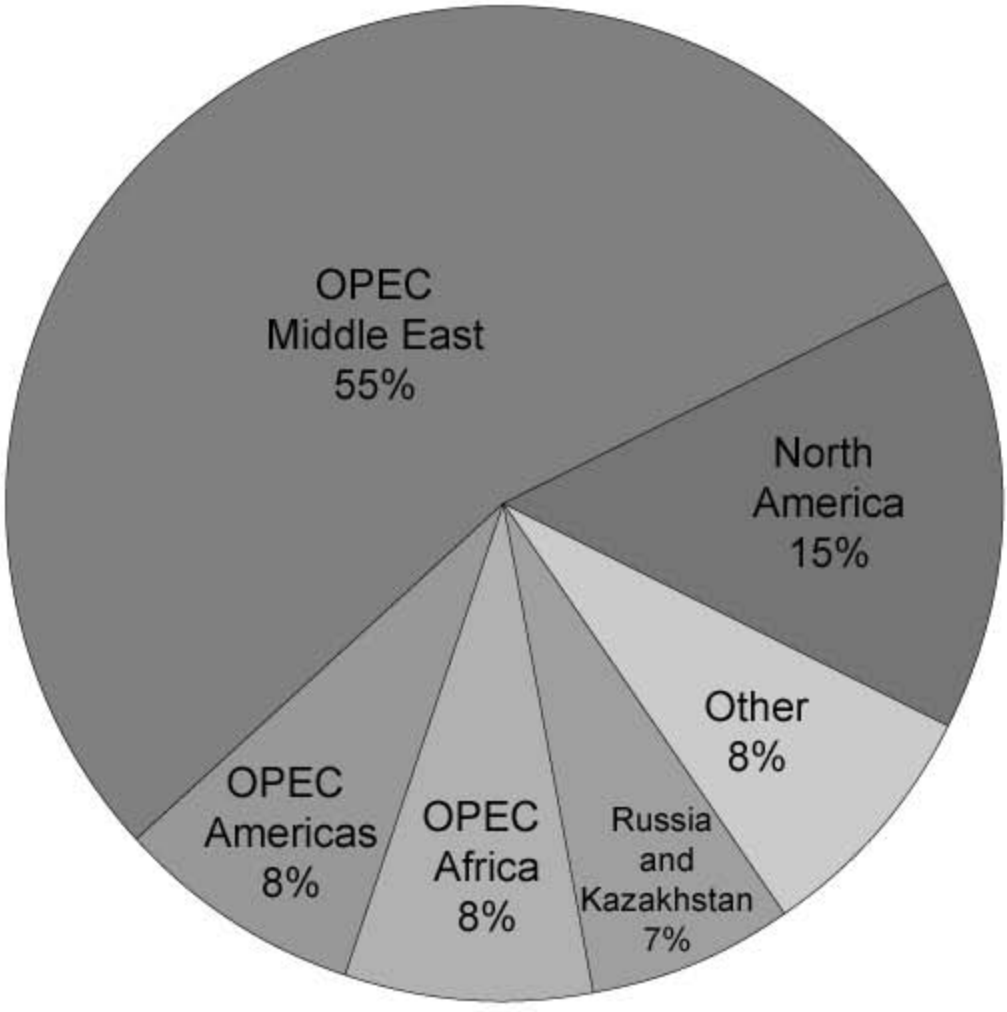
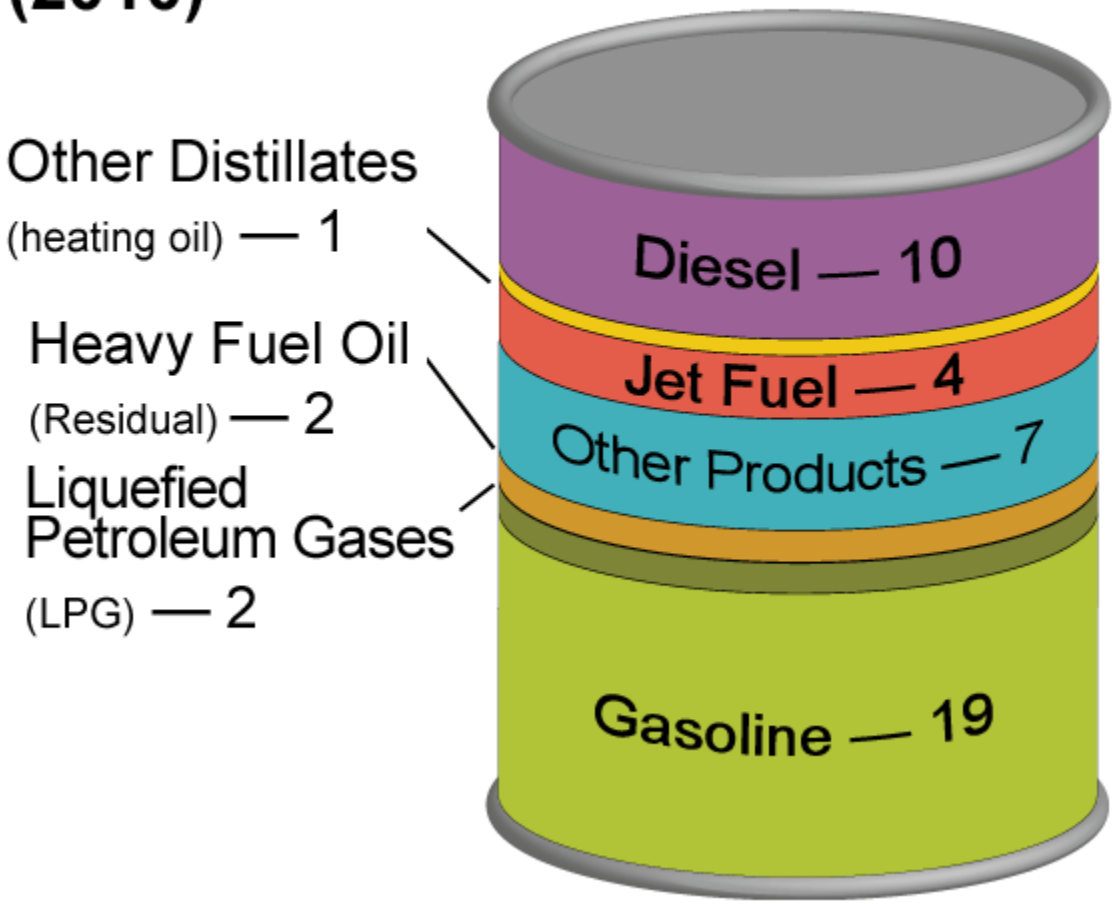


Figure 2:
Shares of Proven Oil Reserve Holders/Locations, 2010



Source: U.S. Energy Information Administration, *International Energy Statistics, 2010*.

Products Made from a Barrel of Crude Oil (Gallons) (2010)



Sources of U.S. Net Petroleum Imports, 2010

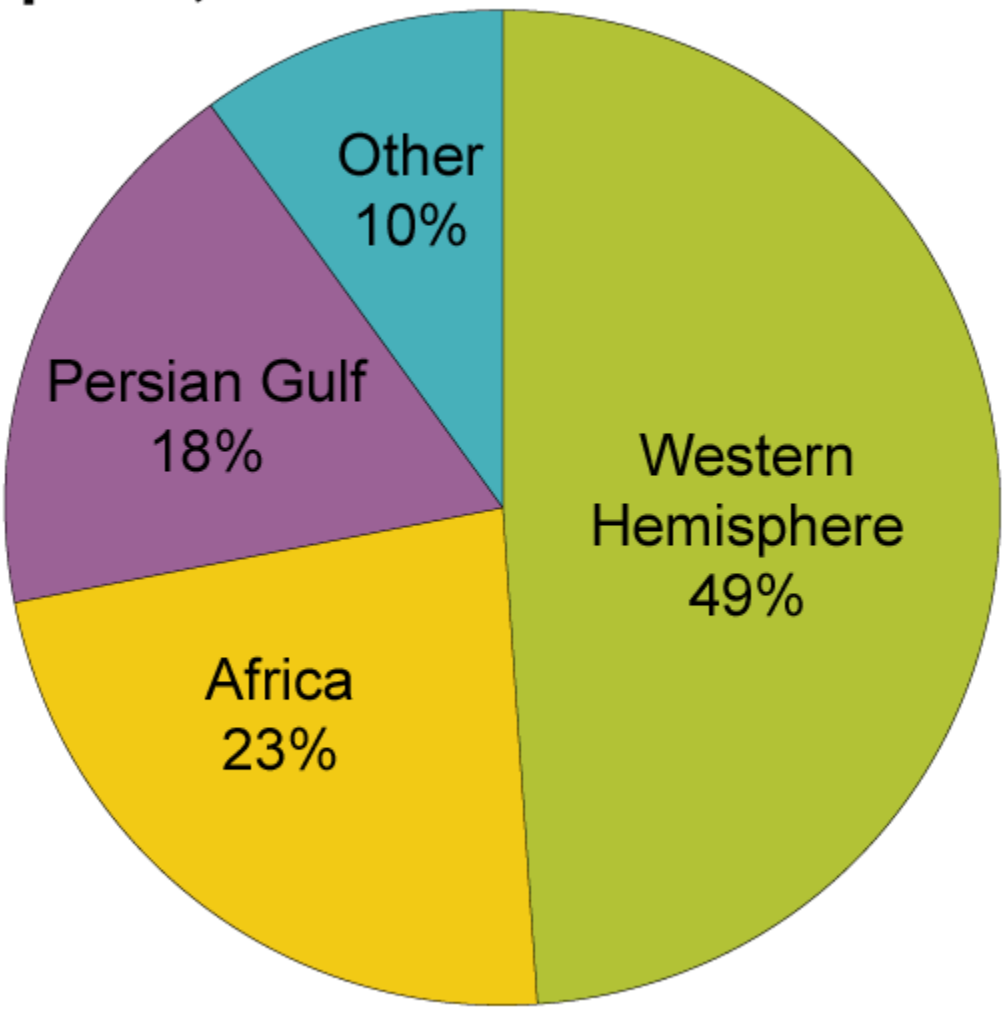


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Figure 5
2010 Petroleum Flow
Millions of Barrels per day
EIA.Gov

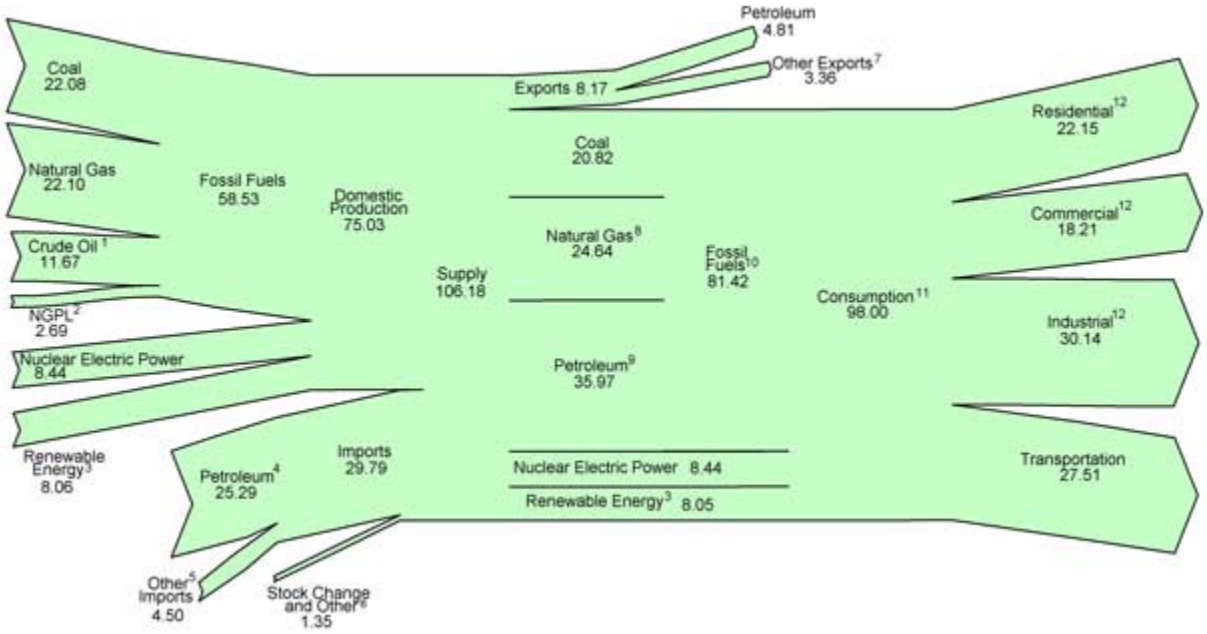
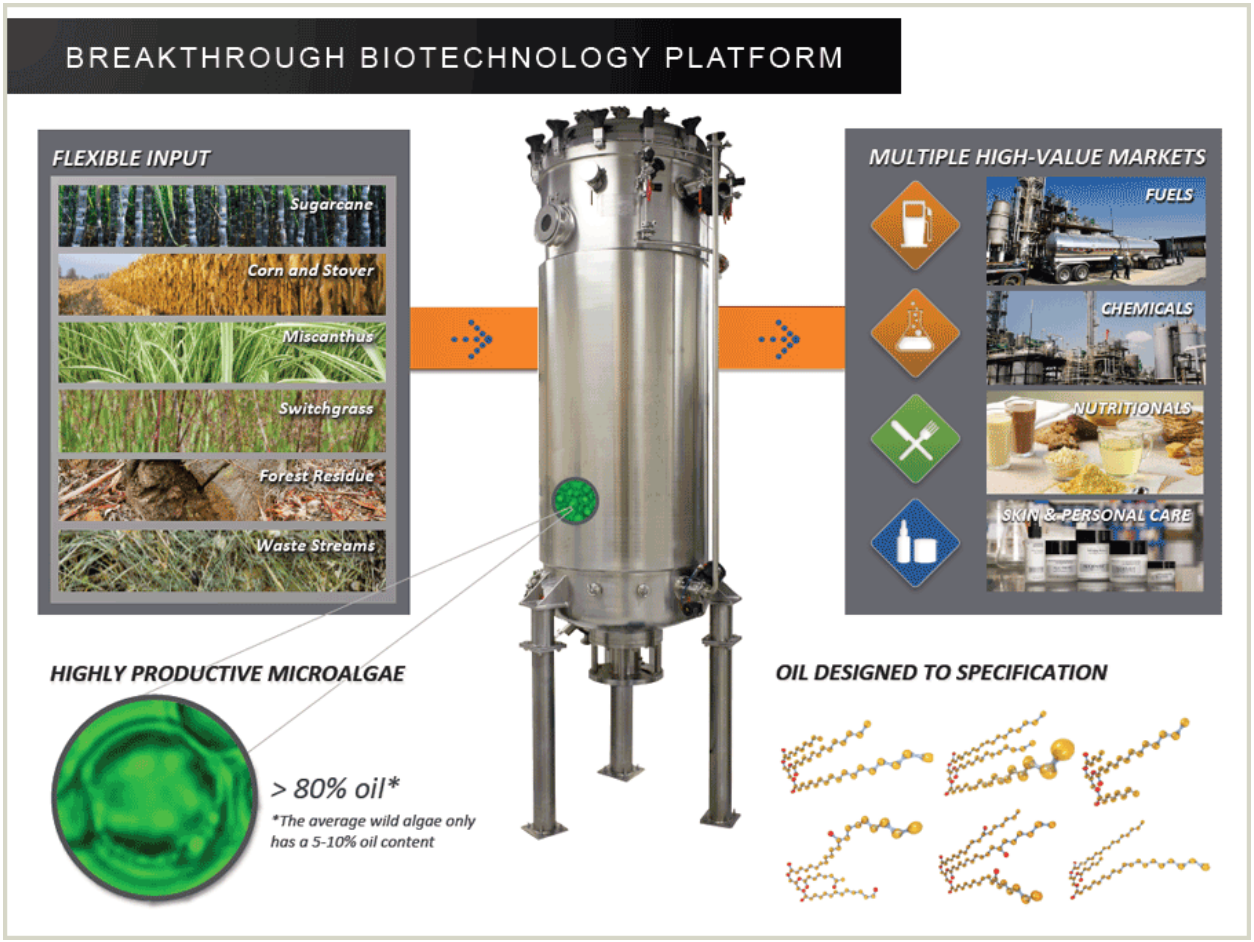


Figure 6

Solazyme's Production Method
http://solazyme.com/technology



GLOSSARY

B100 ……. Pure Biodiesel

CO_2 ……..……..……. Carbon Dioxide

C4I …….. Command, Control, Communications, Computer, and Intelligence

DARPA …….. Defense Advanced Research Projects Agency

DoD ……...…United States Department of Defense

DoE ……..... United States Department of Energy

GSA ……. General Services Administration

JP5 or JP8 ……..……..... Jet Propellant 5 or 8 (Diesel variant)

MRAP ……..……. Mine Resistant Anti-Personnel Vehicle

MTVR …… Medium Tactical Vehicle Replacement

HMMWV ……. High Mobility Multi-Purpose Wheeled Vehicle

U.S. ……..……. The United States of America

USDA …….. United States Department of Agriculture

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